

Extraction of Natural Dye from Flame of Forest Flower: Artificial Neural Network Approach

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Abstract- Due to the harmful effects of synthetic dye, dying has been forced to substitute preparation of dye using natural sources like flowers, leaves, stem, bark etc. These natural dyes are eco-friendly having no side-effects on skin and no disposal problems. In this present study, a computer-stimulated model is developed to get the correlation between the input (variable parameters responsible for extraction) and output parameters (concentration of dye) for dye extraction from the Flame of Forest flower. After a number of trials, the best feed forward neural network has been developed with three layers: an input layer of 3 neurons (extraction time, temperature, amount of flower), a hidden layer with 10 neurons, and the output layer with 1 neuron which gives the total dye present in the solution of Flame of Forest. The developed Artificial Neural Network (ANN) model provides a good interpretation of the experimental data and it shows high correlation between the experimental and simulated values of dye extraction. Finally, experimental and simulated ANN model for total dye extraction from 1 gm and 2 gm flame of forest flowers were statistically compared by % error and Chi-squared test (χ^2) based on the validation data set. Results suggest that experimental data and the error between the experimental and simulated results are very low.

Keywords- Artificial Neural Network; Natural Dye; Flame of Forest Flower; Aqueous Extraction of Dye

I. INTRODUCTION

In present years there has been a revival of the use of dyes and color from natural sources like stem, bark, leaves, roots and flowers for coloring in food industry, cosmetic and textile industry. Until the unexpected invention of widely available and cheaper synthetic dye^[1] of mauveine by English chemist Sir William Henry Perkin in Germany in 1856, people are using natural sources to get different colors- yellow, orange, blue, red, green, brown, grey, etc. for dyeing purpose. This growing demand of natural origin is because synthetic dyes^[1-2] are harmful due to their negative ecotoxicological effects associated with hazards on human health viz. creating skin diseases, lungs problems and environmental problems^[3-6]. Due to these drawbacks, natural dyes are becoming widely recognized throughout the world. Natural colorants are dyes and pigmentary molecules^[7] that are obtained from plant, animal or mineral sources with or without any chemical processing. The advantages of natural dyes^[8-9] are that they are cost effective, renewable, eco-friendly i.e., they do not create any environmental problems at the stage of production or use, maintains ecological balance and has no allergic reaction on skin. The use of natural dyes replaces and reduces significantly the amount of toxic effluent resulting from the dyeing process. In recent years, more than 100,000 dyes are available in market. Worldwide, nearly 1 million tonnes of synthetic dyes are produced annually^[10]. Nowadays, the global demand for natural dyes is increased nearly 10,000 tonnes which is approximately 1% of the synthetic dyes

consumed worldwide^[11]. This need is predicted to grow rapidly in the coming future. It is the need of the day to identify the various resources for the extraction of these dyes. In India huge amount of flowers and herbal materials are being wasted daily. In many cases these highly colored waste plant residues contain considerable amounts of natural dyes. So these wasted flowers can be used for extraction of dye in Textile Industry in place of synthetic dye. Besides application in textile industry, the dyes can also be used in the coloration of food industry for preparing herbal gulal and making different colorful candles.

For the purpose of the work, Flame of Forest (orange-red colour) has been chosen as a natural source for dye extraction.

Another aspect of this work is the development of a feed forward neural network model to predict and develop the total dye extraction from Flame of Forest flowers. The colourful dyes from flowers are extracted by aqueous extraction procedure and the extraction processes are carried out at different temperature with different extraction time and with different amount of flowers. Based on these experimental data an artificial neural network model has been designed. The model was first trained using the experimental data, and then validated with some other set of experimental values.

II. ARTIFICIAL NEURAL NETWORK (ANN) MODELING

An artificial neural network (ANN) is a simplified computational and mathematical model that is inspired by the structure of biological neural networks [Lee et al., 1998]. They are usually used to model complex relationships between inputs and outputs to find out the patterns in data. The main advantage of ANN model over traditional methods is that they do not require the complex nature of the underlying process^[12-16]. Neural networks have been trained to perform complex functions in various fields of application for time series forecasting, pattern recognition, identification, classification, speech, vision and control systems. Artificial neural network has been used successfully for natural dye extraction from flowers. As input variables change continuously, it is very difficult to predict the output dye extraction from Flame of Forest flowers.

The majority of ANN model are feed-forward networks which are mostly mapped from the input data using error back-propagation algorithm. A three-layer network with a linear transfer function with back-propagation neural network (3:10:1) has been designed in this present study. The more the number of neurons, the more is the performance of the neural network in fitting the data. However, too many neurons in the hidden layer may also result in the over fitting of the model data^[17]. To find out the optimum number of neuron in the hidden layer is an important work at the time of network developing.

ANN has three layers or more (as shown in Figure 1): an input layer, which is used to present data to the model; an output layer, which is used to generate an appropriate result to the given input; and one or more inter-connected layers, which are used to perform as a collection of feature detectors. For developing an ANN model, first proper algorithm and transfer function have to be chosen. In this study, different algorithms of transfer function 'poslin' for hidden layer and 'purelin' as the output layer transfer functions are used to train the model. MATLAB 7 (The Mathworks, Inc. ver. 7.0.1) has been used to develop the ANN model using neural network toolbox from the data.

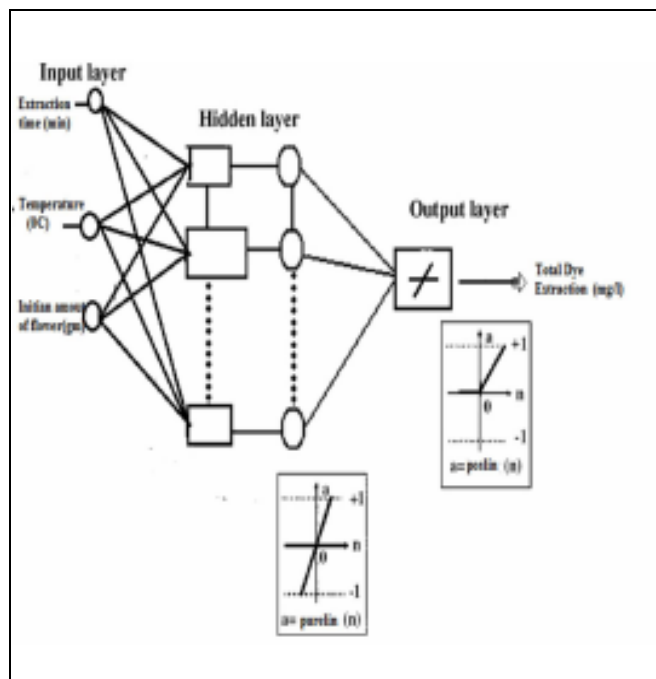


Figure 1 The ANN optimized structure with three input and one output layer

III. RAW MATERIAL USED

Flame of forest tree is a medium sized dry season-deciduous tree, growing to 15m tall. In West Bengal, it is associated with spring (March-April). The flowers of this tree have been used traditionally for dying cloth in a yellow color basanti and also as a colored powder (abiir).

The main coloring pigment of the Flame of Forest flower is butrin (1.5%). Besides butein (0.37%) and isobutrin (0.04%), it also contains flavonoids^[18] and steroids. Other than these in flowers, coreopsin, isocoreopsin, sulphurein (glycoside) and other two with monospermoside and isomonospermoside structures are also identified^[19]. Studies show that isobutrin^[20] slowly changes to butrin on drying. The bright orange red color of the flower is attributed due to the presence of chalcones, pterocarpans^[21] and auronones but other anthochlor pigments are also present.

IV. EXPERIMENTAL METHOD

The color bearing flower samples were collected freshly from Institute garden and separated into individual petals with average size of 1 cm and used for the experiment. Different amount of floral biomass (0.5gm, 1gm, 1.5gm and 2 gm) was taken in Erlenmeyer flask (250ml) and 50 ml distilled water was added to each flask in order to keep the floral materials fully immersed in solvent and kept into the hot air woven at different temperatures (60°C, 70°C, 80°C, 90°C, room

temperature) and the beaker was covered with a watch glass to prevent loss of water by evaporation. Extract samples were taken at different time intervals (30min, 45min, 60min, 90min, 120min and 180min), filtered using filter paper (Whatman, 595-1/2 folded, 110mm diameter) and dried. The optical density of the sample was analyzed with the help of UV-VIS spectrophotometer (HITACHI MODEL NO: 2800, Japan) and the total weight of the extracted dye obtained per gram of flame of forest was determined.

Thus the colourful dye from Flame of Forest flowers were extracted by aqueous extraction procedure and the extraction process was carried out at different temperature, different extraction time and with different amount of flowers to get the optimization point of the process. After the complete extraction of dye, the flowers were taken out from the liquor and then used for extraction of dye, second time.

V. ERROR FUNCTION

An error function assessment is needed in order to evaluate the best fit between the experimental results and the ANN simulated model. The coefficient of determination (R^2) is the most widely used error function. The R^2 coefficient of determination is a measure of how well the model perfectly fits the data. However, several errors analysis methods, such as % error, Chi-squared test (χ^2) have been used to generate the best fitting equation. The lower the numerical value of these errors functions for a given equation, the better is the result^[5].

$$\%Error = \left[\frac{(C_{exp} - C_{simulated})}{C_{exp}} \right] \times 100 \quad (1)$$

$$\chi^2 = \sum \frac{(C_{exp} - C_{simulated})^2}{C_{simulated}} \quad (2)$$

where C_{exp} is the experimental concentration of dye and $C_{simulated}$ is the simulated results from artificial neural network.

At initial ANN model development, it requires many analyses of system variables. The analysis can be determined mainly for cross checking of the system model response with respect to the actual experimental response. If the interaction between the simulated and measured variables starts to fail, then the model can be re trained using other recent data.

Out of the several data points, 15 experimental data sets at different operating condition are used to train and test the ANN structure.

After a number of training trials, the best neural network model is generated. All algorithms and transfer functions may not be suitable for all processes. To develop the suitable network model, finding the appropriate training algorithm, transfer function and number of neurons in all layers are very crucial parameters. The maximum number of epochs (training cycles) is chosen by a trial and error approach. Performance goal and minimum performance gradient are set so as to ensure a model with good performance.

VI. RESULT AND DISCUSSION

The extracted dye from Flame of Forest petals especially has been used as natural colorant for textiles from ancient times. After testing, it is observed that 10 neurons produce minimum value of error of the training and validation sets. In the present work, input variables to the feed forward neural

network are as follows: extraction time (min), temperature ($^{\circ}\text{C}$), amount of Flame of Forest flower (gm). The total extract dye present in the solution (mg/l) is chosen as the experimental response or output variable. The network which gives a coefficient of correlation (R) between the model prediction and experimental results near to 1 is considered to be perfect model and hence selected.

In this study, a positive linear transfer function (poslin) at hidden layer and a linear transfer function (purelin) at output layer were applied. Different algorithms with transfer function are as shown in Table I. Figure 2 shows a comparison between predicted and experimental values of the output variable for test data set by using neural network model. The

plot in this figure has correlation coefficient of 0.985 (>0.8). The values of correlation coefficient (R) are calculated among the best of 10 repeated run. In this study the number of hidden layers and neurons was determined by training different feed-forward networks of various topologies and selecting the optimal one based on minimization of the performance function. A high correlation coefficient of this regression plot signifies the reliability of the neural model with the experimental data. Table 1 shows that the 'Levenberg-Marquardt backpropagation (trainlm)' algorithm with 'poslin' transfer function gives the most satisfactory result than other 'Scaled conjugate gradient', 'Conjugate gradient backpropagation with Polak-Ribiere updates' and 'Resilient backpropagation' algorithm,

TABLE I SUMMARY OF TRIAL AND ERROR METHOD FOR EXTRACTION OF DYE FROM FLAME OF FOREST BY ANN MODEL DEVELOPMENT

Algorithm for Hidden Layer	Function for Output Layer	Transfer Function	Transfer Function	Correlation Coefficient (R)
Levenberg-Marquardt Backpropagation	trainlm	poslin	purelin	0.985
Resilient Backpropagation	trainrp	poslin	purelin	0.951
Conjugate gradient backpropagation with Polak-Ribiere updates	traincgp	poslin	purelin	0.918
Scaled conjugate Gradient backpropagation	trainscg	poslin	purelin	0.907

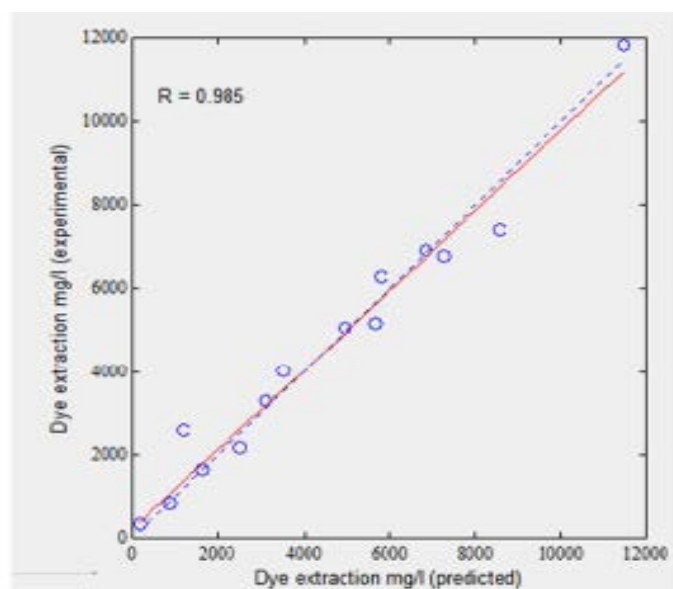


Figure 2 Predicted result vs Experimental result for total Dye extraction from Flame of Forest using by ANN model

which also give a satisfactory result. After a number of error trial method, it is found that based on correlation coefficient value feed-forward neural network is best fitted model for our case study and majority of ANN architectures are feed-forward networks data using back-propagation algorithm. So, feed-forward ANN for the experiment is selected. Feed-

forward ANN is the simplest type and user friendly artificial neural network and the input information moved in only one direction i.e. forward. Figure 3 and Figure 4 compare the ANN simulated result in details with the experimental results. Above figure shows the plot of experimental and simulated ANN model relation for total dye extraction in aqueous

solution from 1 gm and 2 gm Flame of Forest flowers of the 7 data sets used for training. For all the training data sets, the data points of experimental and predicted dye extraction

values more or less coincide with each other. This indicates perfect training of the network.

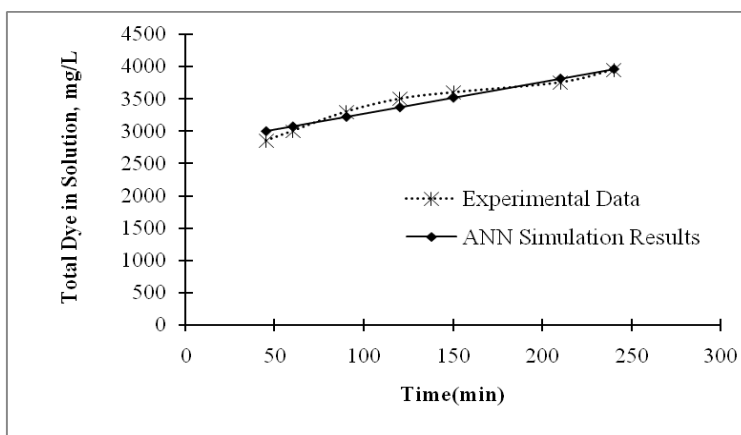


Figure 3 ANN Simulated result vs. experimental result for 1 gm Butterfly Pea flower

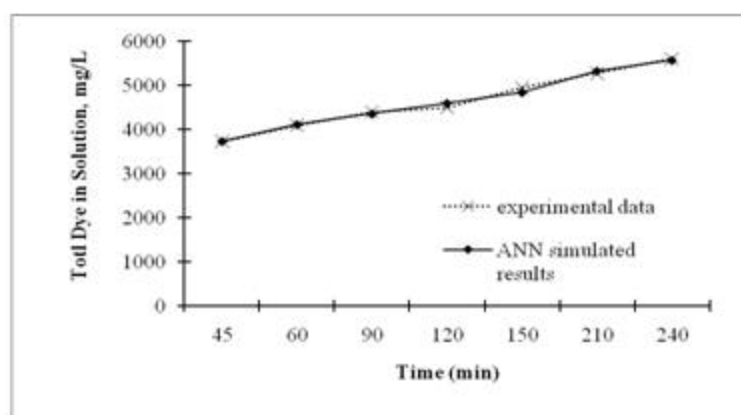


Figure 4 ANN Simulated result vs. experimental result for 2 gm Butterfly Pea flower

Higher error function value suggests that the experimental data is poor fit to the ANN simulated values. From Table II, it is observed that in all cases the experimental and simulated % error is in between 0.16 – 3.75 which is very less. The χ^2 for the experimental and simulated results are also very low

which suggests that the ANN simulation results can represent the experimental data and the error between the experimental and simulated results are very low. The ANN simulation results are in satisfactory agreements with the experimental results.

TABLE II: % ERROR AND χ^2 FOR THE EXPERIMENTAL RESULTS AND THE ANN SIMULATED RESULTS FOR 1 AND 2 GM OF FLOWER

Weight of Flower, gm	Time (min)	% error	χ^2
2 gm	45	-0.27248	0.027582
	60	-0.39756	0.064546
	90	0.912727	0.369928
	120	-2.29733	2.321647
	150	2.082424	2.192214
	210	-1.00398	0.526918
	240	0.596257	0.200644
1 gm	45	-5.35088	7.745629
	60	-2.52367	1.863636
	90	2.351515	1.868719
	120	3.734286	5.070041
	150	2.3175	1.979362
	210	-1.44341	0.771196
	240	-0.16456	0.010679

VII. CONCLUSION

The extraction of yellow dye from Flame of Forest flower is successfully predicted by developing a three-layered neural network with 10 neurons in the hidden layer and using linear transfer function with back-propagation algorithm. There must be a close interaction between the ANN simulated results and experimental results; otherwise it will not be so easy to get desired dyes from the aqueous extraction method. This study shows that all algorithm and transfer functions are not applicable to network design. 'Levenberg-Marquardt backpropagation (trainlm)' algorithm with 'poslin' transfer function gives a most suitable result than the other algorithms for dye extraction. But 'Scaled conjugate gradient', 'Conjugate gradient backpropagation with Polak-Ribiere updates' and 'Resilient backpropagation algorithm' also gives a satisfactory result with the experimental results. The % error function and χ^2 error function were used together to compare the performance of the 1 gm and 2 gm butterfly pea.

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